

New England University Transportation Center



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Final Report

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The New England University Transportation Center is a consortium of 8 universities funded by the U.S. Department of Transportation, University Transportation Centers Program. Members of the consortium are MIT, the University of Connecticut, University of Maine, University of Massachusetts, University of New Hampshire, University of Rhode Island, University of Vermont and Harvard University. MIT is the lead university.

Problem Description

This project has focused on comparing alternative transportation technologies in terms of their environmental and economic impacts. The research is data-driven and quantitative, and examines the dynamics of impact. We have developed new theory and metrics to use in the forward-looking evaluation of a wide range of technologies. In particular, we have developed revised emissions factors for biofuels, to assess their climate change mitigation potential against other alternatives. We have also evaluated the supply risks and the potential for price volatility of biofuels.

Methodology

The methods include statistical data analysis and model development. We studied environmental impacts of a range of biofuels, focusing on their greenhouse gas emissions. We collected emissions data, developed metrics to relate the impact of greenhouse gases to that of carbon dioxide, and tested the performance of metrics against climate mitigation scenarios. Life cycle emissions data was gathered for each of the major fuel pathways examined: gasoline, compressed natural gas, corn ethanol, soy biodiesel, algae biodiesel, and electricity.

We proposed emissions metrics to convert the impact of various greenhouse gases to their carbon dioxide equivalent value. We then test these metrics by generating background scenarios and emissions scenarios resulting from application of the metrics. We propose two metrics in this paper, the Instantaneous Climate Impact (ICI) and Cumulative Climate Impact (CCI). These use equations that are almost as simple as the global warming potential (GWP), but take into account a changing background environmental state (nearness to a radiative forcing threshold). We use a simple set of equations to create the background climate scenarios for generating and testing alternative greenhouse gas emissions metrics.

For economic impacts we have focused on the potential supply risks and price volatility of biofuels. The first step in the research was to examine the volatility of fluctuating inputs. The second step was to investigate diversification as a means to mitigate that volatility.

We built a collection of time series data from various sources on biofuels production, consumption, feedstock yields, feedstock prices, fuels stocks, and mandates. This data was used for empirical estimation and calibration of our models. Based on our conceptual models of the biofuels industry, we have constructed quantitative models to study risk factors. In particular, we have built computational models for processing historical data, estimating correlations and risks, and determining optimal portfolios subject to various constraints.

Findings

Several important findings have resulted from the research. In particular, methane emissions from some biofuels are significant and must be considered in their evaluation. New metrics allow us to identify the dynamic impacts of biofuels greenhouse gas emissions. Supply risks are significant for biofuels but can be mitigated through crop and location diversification.

Fuels emit a variety of greenhouse gases during their life cycles, including methane and carbon dioxide, and these gases have different radiative forcing and removal rates. Methane has roughly 100 times the radiative forcing impact of carbon dioxide when first emitted but decays more quickly, with the two gases having equal radiative forcing roughly 70 years after emission. As a result, the impact of a technology decays over time at different rates. These dynamics are not reflected in static climate

metrics like the GWP, but they mean that the relative climate impacts of alternative fuels are very different when they are evaluated at different points in time.

The two new climate metrics proposed on the research, the CCI and ICI, change over time as the background climate changes, to make technology evaluations more consistent with global climate goals. These metrics show that methane-heavy technologies such as natural gas and algae biodiesel are candidates for bridging technologies, from a climate change mitigation perspective, but do not meet the requirements of long-term mitigation technologies unless their methane emissions can be significantly reduced.

In terms of the economic impacts of biofuels, their fluctuating input feedstocks should be considered and managed upfront to avoid significant social costs. These risks are relevant to biofuels firms, the industry and society as a whole. The risky nature of the biofuel feedstock originates in the variation in crop yields, which may increase in the future due to factors such as climate change and cultivation in less productive areas. These supply risks can result in substantial fuel price volatility.

Diversification is a relevant strategy to mitigate these supply risks. Our evidence suggests that geographical distance may help reduce portfolio risks. We show that the optimal portfolio can lower risks significantly, with some reduction in expected yield. We estimate that diversifying the production of corn feedstock, for example, from the most productive US state to other locations reduces the average yield by roughly 10% while the standard deviation of yields decreases by 50%. In addition, crop diversification may also significantly mitigate risks.

Conclusions and Recommendations

We have found that the dynamic performance of biofuels is critical in evaluating their mitigation potential. Emissions factors that reflect the dynamic radiative forcing contribution of greenhouse gases can effectively assess climate impacts of alternative fuels. The CCI and ICI represent two approaches to quantifying these impacts. Our research also shows that biofuel feedstock supply risks can be substantial. The variation in crop yields, inelasticity of demand, and a fluctuating demand, argue for the importance of studying and mitigating biofuels supply risks. As we show, risk reduction can be achieved by choosing an combination of crops and production locations.

Research Output

Journal publications:

- Ghoddusi H, Trancik JE, Biofuels Supply Risks and Energy Security Concerns, in preparation for submission.
- Edwards MR, Trancik JE, Approximate Emissions Timing Improves Energy Technology Evaluation, in preparation for submission.

Conference proceedings:

- Ghoddusi H, Trancik JE, Supply Risks of Biofuels, US Association for Energy Economics/ International Association for Energy Economics, North American Conference, 2012 (abstract proceedings).
- Ghoddusi H, Cross-Call D, Trancik JE, The Supply Risks and Resilience of Biofuels, 3rd International Engineering Systems Symposium, CESUN Proceedings, 2012.

Class material:

Material from this project has been incorporated into two MIT classes: ESD.124, Energy Systems and Climate Change Mitigation, and ESD.125, Mapping and Evaluating New Energy Technologies.